HIGH INTENSITY INFRASONIC TUNABLE RESONANT ACOUSTIC TEST CELL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of acoustic test chambers or cells. More particularly, the invention is directed to an apparatus and method for providing an acoustic test chamber or cell that achieves, in air, very high-intensity infrasonic to low-sonic frequencies in moderately large test volumes with very pure sinusoidal waveforms.

2. Description of Related Art

High-intensity acoustic test chambers are well known in the art. Previous high-intensity acoustic test chambers capable of operation at fundamental frequencies below 100Hz include high-intensity flow-modulator-driven non-resonant chambers, standing-wave resonant chambers driven by flow modulators or loudspeakers, and piston-driven sealed chambers.

Each of these known high-intensity acoustic test chambers has significant limitations. High-intensity flow-modulator-driven non-resonant chambers as devices are not capable of efficient operation or the production of reasonably undistorted sound (sine waves) below about 30 Hz.

Standing-wave resonant chambers driven by flow modulators or loudspeakers, by their nature, have strongly non-uniform acoustic fields in their test volumes and require that the test chamber have a long dimension of at least one-half the wavelength of the lowest usable frequency. That is, their long dimension must be at least 11 m's at 30 Hz.

Piston-driven sealed chambers require a mechanical drive to accelerate and decelerate a piston which serves as one wall of a test chamber or test cell. This acceleration/deceleration takes place at very high rates which restricts these devices to very low frequencies and small test volumes, typically less than $1m^3$.

SUMMARY OF THE INVENTION

The present invention generates continuous high-intensity acoustic fields with clean sinusoidal waveforms, in air, in a moderately large volume, and in the infrasonic to low-sonic frequency range (1 Hz to 30 Hz).

Embodiments of the present invention employ a test volume as part of a Helmholtz resonator that may include one or more volumes.

For both single-volume and multi-volume embodiments, generation of an infrasonic to low-sonic (e.g., 1 Hz to 30 Hz), very high-intensity, spectrally pure acoustic field in volumes of

useful size (e.g., $5m^3$) is accomplished by using the volumes themselves as parts of a Helmholtz resonator. These volumes are each directly driven at a chosen frequency and intensity by an external acoustic energy source.

In one embodiment of either a single or multiple volume test cell, each volume is directly driven at a chosen frequency and intensity by a modulated air or gas flow introduced into one of the volumes. In another embodiment of a single or multiple volume test cell, each volume is directly coupled to acoustic transducers. In either embodiment the acoustic field in a given test volume can be tuned to a predetermined driving frequency by varying the geometry of an associated duct/tuning port connected to said volume but otherwise not directly connected to the acoustic energy source. The intensity and spectral purity of the acoustic signal in each volume are enhanced by the resonance of its associated duct/tuning port.

In another embodiment of a multi-volume test cell, each test volume is isolated from an acoustic energy source by means of dividing each Helmholtz resonator volume into two volumes (input volume and test volume) in which the input and test volumes are connected to one another by a duct/tuning port. Air is exhausted

from the input volume to the exterior through a long duct or other high acoustic mass. Isolation of the test volume eliminates any possibly undesirable contaminants or characteristics of the air or gas flow (e.g., noxious gases, excessively low or high temperatures) associated with that flow. Further, isolation eliminates the unidirectional gas flow from the acoustic energy source through the resonator duct/tuning port and consequent acoustic losses in the duct associated with turbulence and loss of acoustic mass.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an embodiment of the present invention employing a single volume acoustic test cell according to the present invention.

FIG. 2 illustrates another embodiment of the present invention employing a dual-volume Helmholtz resonator test cell driven by a compressed-gas source through a flow modulator or other acoustic source.

FIG. 3 illustrates another embodiment of the present invention employing an electrical analog equivalent circuit of the dual-volume acoustic test cell illustrated in FIG. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the present invention, illustrated in FIG. 1, comprises a rigid airtight chamber 10 enclosing a test volume 20, typically about 5 m^3. A high-intensity repetitive acoustic signal or air pressure variation, typically with a low fundamental or repetition frequency (single Hz to tens of Hz) is introduced into the test volume 20 of this chamber by means of an acoustic energy source. One such means is a source of compressed air (air compressor) 30 and a flow modulator 40 which periodically varies the flow of compressed air from the source into the volume 20. It is to be understood that the periodic air pressure variation generated by the acoustic energy source means is not restricted to be sinusoidal. The test volume 20 and an associated tuning port or duct 50 that communicates with outside free air constitute a Helmholtz resonator 60 that can be tuned by means of varying the internal length and/or cross section of the tuning port 50 to the frequency that corresponds to the fundamental frequency of the periodically varying air or gas flow from the flow modulator 40 or other acoustic source. The intensity and spectral purity of the sound in the test volume 20 are thereby amplified by the Helmholtz resonance of the volume 20 tuning port 50 combination. The maximum dimensions of the test volume 20 are chosen to be less

than one-half of the wavelength corresponding to the maximum operating acoustic frequency of the apparatus. With this choice of maximum dimensions, standing waves are not generated in the test volume 20 and the acoustic field in the test volume 20 is highly uniform.

Another embodiment of the present invention is illustrated in FIG. 2 and operates in a similar manner. The apparatus illustrated in FIG. 2 includes a rigid chamber 70 enclosing two volumes 80 and 90 connected by a duct/tuning port 100 which rigid chamber and tuning port as a unit act as a Helmholtz resonator that is tuned by varying the length and/or cross-section of the duct/tuning port 100. In this embodiment the second (test) volume 90, communicates with the first (input) volume 80, only by means of the duct/tuning port 100 and (with the possible exception of an optional relatively low-volume positive-pressure ventilating air input with very high acoustic mass and/or resistance 200) is airtight to air and sound flow to the outside. The unidirectional, or DC, component of the air flow from the flow modulator 40 or other acoustic source and air compressor 30 is exhausted to the outside free air through a long pipe of small diameter 110 that, by virtue of its high

acoustic mass, passes only acoustic energy at frequencies below the operating frequencies of the system.

An electrical circuit analog that illustrates the principle of the two-volume device, and that may be used to calculate its operating characteristics, is illustrated in FIG. 3. The volumes constitute acoustic compliances that correspond to electrical capacitances 120 and 130. The acoustic masses of the duct/tuning port and DC exhaust vent correspond to electrical inductances 140 and 150, respectively. ~~Losses in acoustic mass~~ Acoustic losses correspond to the resistances 160 - 190, with the flow modulator or other acoustic source being represented by a periodically varying pressure in series with an acoustic loss corresponding to resistance 160. The operating frequency of the circuit is determined by the series combination of the volume compliances 120 and 130 with the duct/tuning port mass 140.

It is to be understood that an electrical circuit analog of the first embodiment, as illustrated in FIG. 1, is a simplification of FIG. 3 in which elements 130, 140, 180 and 190 are eliminated, the compliance 120 becomes that of the single test cell or chamber, and the flow vent mass 150 and vent acoustic loss 170 become the tuning port mass and loss, respectively. In this case, the

operating frequency of the circuit is determined by the parallel combination of the chamber compliance 120 and the vent/port mass 150.

From the foregoing it will be obvious to one skilled in the art that numerous modifications and variations can be made without departing from the spirit and scope of the novel aspects of the current invention. For example, the same arrangements of components, appropriately sized, may be applied at frequencies outside the ~~5~~ 1 Hz to 30 Hz infrasonic to low-sonic frequency range and there may be more than one external source for acoustic fields coupled to a multi-cell acoustic test apparatus. It is to be understood that no limitation of the scope of the present invention with respect to the specific embodiments illustrated is intended or should be inferred, but the scope of the present invention is to be defined solely by the attached claims.